Residential Energy Consumer Education

Agricultural Extension Service
University of Minnesota
St. Paul, MN 55108

1978 Pilot folder. Please send comments to the author at the above address.

UNDERSTANDING HEAT LOSS AND ENERGY CONSERVATION CODES

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INTRODUCTION

Because heat loss from houses is a major use of energy in our climate, the State of Minnesota has an "energy code" for new house construction. Although the code applies to new houses, the underlying principles are useful for planning improvements to older houses as well. The energy code is a minimum standard for new houses, and is meant primarily to prevent excessive heat loss. Many builders use better construction than code requires because the extra cost is repaid by years of heat savings.

There are a few basic ideas that are very important to begin with. The house can be viewed as a "kit" of parts (see Figure 1 on page 2). When these parts are put together in a finished house, some heat loss occurs where parts are joined together because of air leakage. Other heat loss occurs directly through the parts themselves because of conduction. A thermos bottle of hot coffee, for example, cools off even if the lid is kept tight. Slow heat loss occurs through the walls of the bottle, despite their excellent insulating value. The rate of heat loss is slow in a thermos bottle. The rate of conduction heat loss through a given part of a house depends on the thickness, materials, and exposed surface area of the part. The rate is very important.

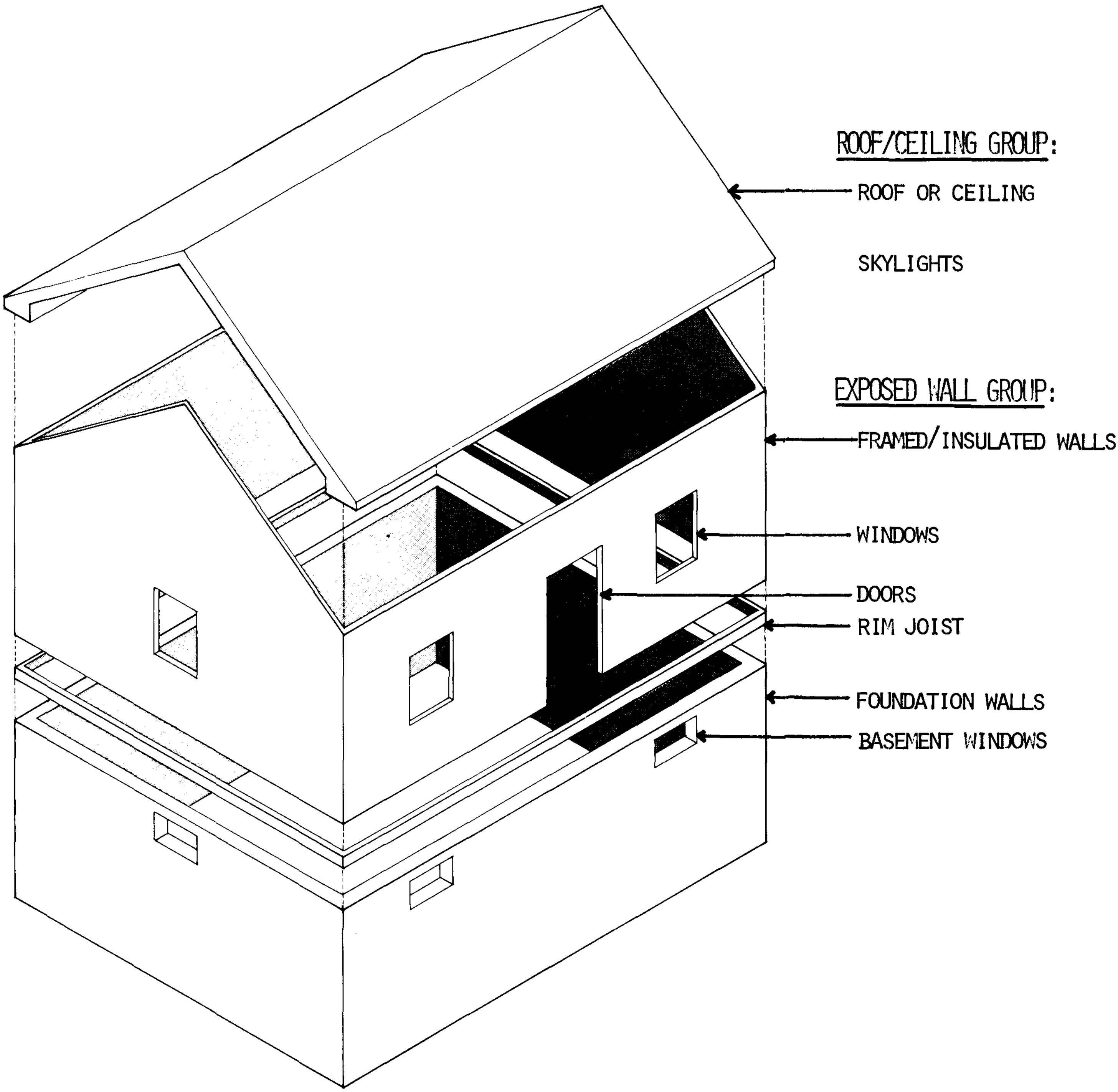
To slow the rate of conduction heat loss through a particular part of the house, you have up to three choices: (1) alternate materials with greater insulating effect, (2) thicker layers of material, (3) smaller area of the part (e.g., smaller windows or less windows). These choices do not apply equally to all parts, however. This folder is written to help you with the important choices for typical construction. To slow the rate of air leakage heat loss, you must caulk holes and cracks, and weatherstrip doors and windows.

This folder will explain how to estimate air leakage heat loss, and how to figure the conduction heat loss through the individual parts of a house. A worksheet is provided in the middle of the folder to allow you to estimate heating cost per year due to each heat item. Cost per year can be used to decide if it is worth improving that item. For example, if better wall insulation added $200 to the cost of your house, but would save $40 per year in heating, then it should be worth buying the better material. The extra "front-end" cost will be repaid in five years, and the house will have better resale value if you can show low heating bills. The worksheet helps you to figure the payback time of improvements for any part of the house.

A House is an Envelope

A finished house wraps your family like an envelope. Each exterior part of the house is a part of the envelope, enclosing a bubble of warm air during cold Minnesota winters. Certain exterior parts have special purposes besides holding in the bubble of warm air. Windows let in light and give us a view of the surroundings. Doors allow us to come and go. In the summer, windows and doors allow cool breezes to keep the house comfortable. In winter, however, windows lose more heat for their size than any other house part. Careful window planning is needed.

FIGURE 1. KIT OF HOUSE PARTS



The Minnesota Energy Code groups together parts that make up the exposed walls--doors, windows, exterior framed wall areas, rim joist area, and exposed foundation areas. Items that make up the roof-ceiling are in another group (see Figure 1).

For an unfinished attic, in which cold air circulates, the ceiling area directly below the attic would be the important "exterior part".

In a finished attic, where the roof itself should be insulated, the main ceiling, kneewalls, and dormer ceilings are the important "exterior part". All of a hipped roof would be part of the "roof-ceiling" group for a house with finished attic. The ends of a gable roof would be considered exterior walls for a house with a finished attic. In the worksheet you will need to add up areas to find the total area of each type of part.

A house could be compared with an inner tube having several leaks. With more leaks, or larger ones, one would have to pump harder to keep the tire full. A house with more "leaks" for heat loss requires the furnace or woodstove to work harder, and that costs money! Calculating the amount of heat loss from a house is somewhat complicated, but the savings will reward your careful planning to reduce heat loss.

Outdoor Temperature and Heating Units

Heat loss rate also depends on a difference of temperature, as well as the thickness, material, and area of a house part. When it is 68° Fahrenheit outside, there is no heat loss through any part of the house because 68° is the same as the inside of the house. There is no temperautre difference under these conditions. But when outdoor temperature starts to drop on cold nights in early fall, heat loss occurs because of the difference between 68° (inside) and a lower outside temperature. Down to about 65°, the difference does not have a noticeable effect inside because small heat sources (people, lights, appliances) will keep the house warm. Below 65°, a big heat source (the furnace or electric heating) will be used to maintain a comfortable temperature indoors. The U.S. Weather Bureau records how far the temperature is below 65° on the average each day. The average "below 65°" for a one day period (24 hours) are called "heating-units" or "degree-days". For example, if the outside temperatures that occur during a 24-hour period averaged out to 60° F, we would say that 5 degree-days occurred. Think of a "man-day" of work. One man working for one day is a man-day. Similarly, one degree below 65° for one day is one "degree-day". Many newspapers print a weather report including degree-days or "heating units". Appendix 1 gives a list of degree-days per year for cities in Minnesota.

Air Leakage Heat Loss

One of the two basic types of heat loss is due to air leakage. Leakage occurs around window frames, door frames, window sash, doors, outside faucets or electrical fixtures, foundations, and wherever a crack or hole allows air to escape. It also occurs when doors or windows are opened and when bathroom or kitchen ventilators pull air out of the house.

Whenever there is a wind, cold air is pushed in through leaks on the windward side of the house, and warm air leaks out on the leeward side (a good reason for planting wind-breaks). Even when there is no wind, a house with combustion-type heating (gas, oil, or wood) will lose some warm air out the chimney. Since air is needed for combustion, the furnace sucks air out of the house. Cold air leaks into the house to replace the warm air used in combustion. Fireplaces are notoriously bad for this because they often pull much more warm air out of the house than needed for combustion.

Your house should minimize air leakage, but if you plan for an extremely tight house, you may want to check with a heating contractor. Be sure that adequate "breathing" is available for your furnace or wood-burning system. One method is to let your furnace breathe fresh air from outside, by running a duct from outside to a location near the furnace. A 1977 book by A.J. Hand, a Popular Science magazine editor, titled "Home Energy How-To," gives tips for furnace breathing as well as many other practical improvements. (See Reference list)

To know how much heat is lost by air leakage, we need an estimate of air change per day. For example, 24 air changes per day means that the entire inside volume of the house leaks out in one hour and is replaced by outside air. Multiply floor area by ceiling height to obtain volume, but do not include the basement volume unless more than one-third of the basement walls are exposed. For example, a one-story house with 800 square feet of floor and 8 foot high ceiling would have 6400 cubic feet of volume. To calculate heat loss, use Equation 1.

EQUATION 1. AIR LEAKAGE HEAT LOSS

______	=	______	X	______	X	______	X	0.018
HEAT LOSS PER YEAR (BTU/year)		AIR CHANGES PER DAY (see below)		VOLUME OF HOUSE (ft^3)		HEATING UNITS (degree-days per year)		HEAT CAPACITY $\left(\frac{BTU}{ft^3 - {}^\circ F}\right)$

"tight"	house	12 air changes per day
"average"	house	24 air changes per day
"loose"	house	48 air changes per day

The factor 0.018 is the capacity of air to contain heat. It must be used to translate air change into heat loss. Use Appendix 1 to look up the number of heating units in your location. To obtain cost per year, multiply "heat loss per year" by your local "adjusted energy price". See page 10 for the method to adjust your fuel price---according to the type of heating system you have.

Air Leakage and Energy Code Requirements

Air leakage can be estimated part by part with detailed methods, but the end result is normally between 12 to 24 air changes per day for a well-built house. See reference 5 if you are interested in detailed methods of estimating air change. Otherwise choose a value between 12 and 24 air changes per day depending on the quality of windows and doors you buy and the care taken in caulking and weatherstripping. If you have an "above-average" house use 18 and if you have a "super" house use 12.

Overall air leakage rate is difficult to estimate because it varies with family habits, furnace or fireplace operation, and windiness in your location. The Minnesota Energy Code, therefore, does not prescribe a maximum overall air change rate. The code does prescribe standards for window and door air leakage. Code requires that windows have no more than 0.5 cubic feet per minute (cfm) of air leakage per foot of crack (around and between sash). The code requires that exterior doors have no more than 1.25 cfm per square foot of door area, and no more than 0.5 cfm per square foot of sliding glass door area.

Window and door manufacturers can specify whether their products meet these standards. Be sure to ask before you buy.

UPDATE INFORMATION

RESIDENTIAL ENERGY CONSUMER EDUCATION

(Roger A. Peterson, Extension Specialist Residential Energy)

Page 10 of Folder 389 gives energy prices as of 1977. Since printing, new price information has become available. Prices as of the summer of 1978 are listed below. Refer to the map on page 12 of Folder 389 for region boundaries.

APPROXIMATE LOCAL ENERGY PRICES (1978)*

Region	Natural Gas		Electric Space Heat**		Fuel Oil		Propane	
(p. 12)	$ per MMBtu	$ per mcf	$ per MMBtu	¢ per kwh	$ per MMBtu	¢ per gal	$ per MMBtu	¢ per gal
1	$3.26	$3.26	$ 7.53	2.57¢	$3.18	44.9¢	$4.28	39.4¢
2	$3.21	$3.21	$ 8.70	2.97¢	$3.30	46.5¢	$4.33	39.8¢
3	$2.57	$2.57	$11.46	3.91¢	$3.36	47.4¢	$4.74	43.6¢
4	$3.25	$3.25	$ 7.00	2.39¢	$3.23	45.6¢	$4.61	42.4¢
5	$2.85	$2.85	$11.87	4.05¢	$3.25	45.8¢	$4.53	41.7¢
6E	$2.87	$2.87	$ 8.50	2.90¢	$3.20	45.1¢	$4.52	41.6¢
6W	$2.52	$2.52	$ 7.36	2.51¢	$3.17	44.7¢	$4.33	39.8¢
7E	$2.39	$2.39	$ 9.14	3.12¢	$3.19	45.0¢	$4.54	41.8¢
7W	$2.56	$2.56	$ 8.03	2.74¢	$3.19	45.0¢	$4.30	39.6¢
8	$2.33	$2.33	$ 7.44	2.54¢	$3.16	44.6¢	$4.04	37.2¢
9	$2.80	$2.80	$ 7.68	2.62¢	$3.20	45.1¢	$4.16	38.3¢
10	$1.96	$1.96	$ 8.35	2.85¢	$3.17	44.7¢	$4.23	38.9¢
11	$2.63	$2.63	$ 7.42	2.53¢	$3.27	46.1¢	$4.66	42.9¢

* Data for the price of gas per mcf, electricity per kwh, fuel oil per gallon, and propane per gallon was taken from "Residential Energy Prices in Minnesota", Summer 1978, by the Forecasting Division, Minnesota Energy Agency, 980 American Center Building, 150 East Kellogg Boulevard, St. Paul, MN 55101, (612) 296-5175.

** The electricity prices given are based on an average of the electric bills in each region after general-use electric consumption has been subtracted. The electric utilities or cooperatives in your region may not have uniform rate structures, however, so your actual cost may be above or below the average. For the current cost of electricity for space heating, call your electric company.

ERRATA SHEET

RESIDENTIAL ENERGY CONSUMER EDUCATION

Folder Series - 1978

Extension Folder 389 - "Understanding Heat Loss and Energy Conservation Codes:

On page 10, Table 4 should be corrected in the column headed by "Fuel Oil, $ per MMBtu". The correct 1977 prices of fuel oil per MMBtu by region are listed below.

Region (see map on P. 12 of Folder 389)	Fuel Oil Price per MMBtu
1	$3.19
2	3.19
3	3.19
4	3.19
5	3.19
6E	3.12
6W	3.12
7E	3.12
7W	3.12
8	3.12
9	3.12
10	3.12
11	3.12

Extension Folder 387 - "Minnesota Energy Prices"

On page 1, Table 1 should be corrected in the column headed by "Fuel Oil, $ per MMBtu", to read as shown above.

ERRATA SHEET

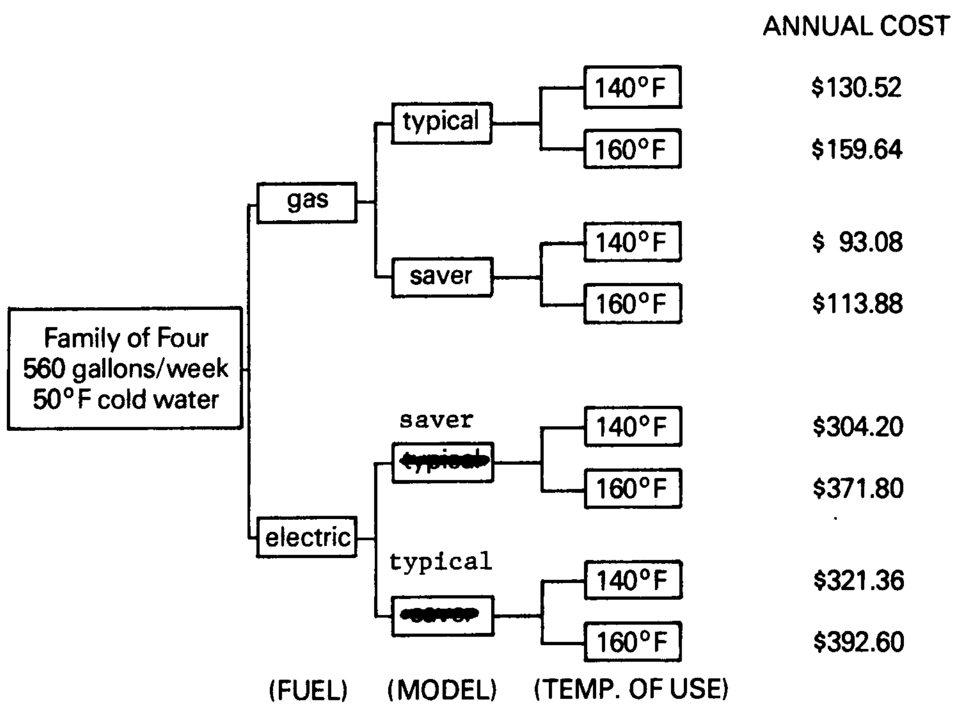
RESIDENTIAL ENERGY CONSUMER EDUCATION

Folder Series - 1978

Extension Folder 388 - "Hot Water and Your Home Energy Budget"

On page 2, Figure 1 should be corrected as shown below.

Figure 1. Example of Hot Water Worksheet Results



(see reverse side also)

Conduction Heat Loss

The other basic type of heat loss occurs directly through the parts of a house by conduction. Any material will conduct heat from one side to the other if there is a temperature difference. Building materials, including glass windows, are rated for heat loss per square foot of surface area. The rating number is called "U-Value" and expresses heat loss in units of BTU per hour per square foot per ^{o}Fahrenheit (BTU/hr - ft^2 - ^{o}F). Table 1 gives U-Values of representative house "parts" such as walls, windows, doors, and roofs. Smaller U-Value means slower heat loss rate.

No attempt is made in this folder to show every conceivable type of construction, combination of materials, or components that are possible for any house design. For more complete information on U-Values see further references listed at the end of this publication. For house parts that are different in materials or thickness than those listed in Table 1, the R-Value method should be used (see Appendix 2).

During a year, the amount of heat loss by conduction through a house part is figured by Equation 2.

EQUATION 2. CONDUCTION HEAT LOSS

$$\underset{(\mathrm{BTU/year})}{\text{HEAT LOSS PER YEAR}} = \underset{\left(\frac{\mathrm{BTU}}{\mathrm{hr - ft^2 - {}^{o}F}}\right)}{\text{U-VALUE OF HOUSE PART}} \times \underset{(\mathrm{ft}^2)}{\text{AREA OF HOUSE PART}} \times \text{24 HOURS/DAY} \times \underset{\left(\frac{\mathrm{degree - days}}{\mathrm{year}}\right)}{\text{HEATING UNITS}}$$

Table 1. U-Values and Heat Loss of Typical Building Parts

Description of House Part	U-Value [1] (Btu/hr-ft^2-^{o}F)	R-Value [2] (hr-ft^2-^{o}F /BTU)	Heat loss from each square foot per year for 8200 degree-days [3]
Two by four stud walls on 16" spacing with 3½ inch fiberglass batt (fiberboard sheathing, gypsum board interior)	.070	14.26	13,780 BTU/yr
Two by four stud wall with 3½ inch fiberglass batt and 1 inch styrofoam-type panel insulation replacing fiberboard sheathing	.056	17.74	11,020 BTU/yr
Two by six stud wall on 24 inch spacing with 5½ inch fiberglass batt (fiberoard sheathing, gypsum board interior)	.046	21.83	9,050 BTU/yr

Table 1. is continued on the next page.

TABLE 1 (continued)

Description of House Part	U-Value [1] (Btu/hr-ft^2-^{o}F)	R-Value [2] (hr-ft^2-^{o}F /BTU)	Heat loss from each square foot per year for 8200 degree-days[3]
Typical rim joist construction (fiberboard sheathing, 3½ inch batt tucked along rim joist)	.060	16.72	11,810 BTU/yr
Rim joint construction with 1 inch styrofoam in place of fiberboard sheathing	.050	20.07	9,840 BTU/yr
Foundation wall with 8 inch lightweight concrete block (no insulation)	.359	2.78	70,650 BTU/yr
Foundation wall with 8 inch concrete block and 1 inch styrofoam	.109	9.13	21,450 BTU/yr
Single glass window and storm window	.560	1.79	109,810 BTU/yr
Double glass window and storm window (or triple glass window)	.360	2.77	70,850 BTU/yr
Typical 1 3/4 inch solid wood door, with combination storm door	.240	4.16	47,230 BTU/yr
Steel door with 1 3/4 inch polystyrene foam core	.100	10.00	19,680 BTU/yr
Ceiling with ½ inch gypsum board nailed to two by six rafters on 16 inch spacing, insulated with 5½ inch loose-fill fiberglass	.062	16.03	12,200 BTU/yr
Same ceiling construction, insulated with 11 inch loose-fill or batt fiberglass	.030	33.05	5,900 BTU/yr

[1] In a stud wall, or rafter ceiling, the U-Value is calculated by taking an average of the heat transmission through the studs or rafters with the transmission through the insulated cavity area between rafters.

[2] R-value is equal to 1 divided by the U-value (pocket calculators are handy for finding reciprocals).

[3] Column 3 represents the heat loss per square foot from house parts in the Minneapolis-St. Paul area. Northern areas of the state may have as much as 25 percent greater heat loss (depending on the degree-days per year listed in Appendix 1). To find the <u>cost per square foot per year</u>, multiply the heat loss in column 3 by your local "adjusted energy price". See page 10 for the method of figuring "adjusted energy price".

WALL CONDUCTION AND ENERGY CODE REQUIREMENTS

Conduction heat loss must be estimated part by part. There is no quick, simple method because each part of a house has a different U-Value. Windows, for example, have high U-Values and high heat loss. We accept this because of light, view, and summer ventilation needs. Doors are somewhat better (they have a lower U-Value than windows). Double-doors and "thermal doors" have even lower U-Value. Insulated framed walls have the lowest U-Value in the wall group. If heating was our only consideration, a house would not have windows or doors. That is not realistic, of course, but a house should have a reasonably good average U-Value for the wall group. Too many windows raise the average too far. Thicker insulated walls and insulated doors lower the average. A "balancing" of areas and U-Values is required to reach a reasonable average. Code requires the average U-Value for the wall group to be no greater than 0.17 for most of Minnesota. In terms of average R-Value*, the wall group must be no less than 5.88. Equation 3 below is used to determine average U-Value (U_{avg}) of the wall group. Code requirements vary with coldness of local weather---see Appendix 1 for the required U_{avg} in your location.

EQUATION 3. AVERAGE U-VALUE IN EXPOSED WALLS

$$U_{avg} = \frac{U_W A_W + U_R A_R + U_F A_F + U_G A_G + U_D A_D}{A_{Total}}$$

where U_{avg} = Average U-Value in wall group

U_w = U-Value insulated frame wall

A_w = Area of insulated frame wall

U_r = U-Value rim joist

A_r = Area of rim joist

U_f = U-Value of exposed foundation

A_f = Area of exposed foundation

U_g = U-Value of window glass

A_g = Area of window glass

U_d = U-Value of doors

A_d = Area of doors

A_{Total} = Total gross area of exposed walls ($A_w + A_r + A_f + A_g + A_d$)

*R-Value is "thermal resistance". If U-Value is given, R-Value can be found by taking the reciprocal of U-Value (R = 1/U). Or, if R-Value (resistance) of individual layers are known, total R-Value can be found by adding all the "resistances". (See Appendix 2 for full explanation). Table 1 has R-Values and U-Values worked out for common house parts.

WINDOW PLANNING

For an example of "balancing" of areas in the wall group, see Table 2. A house with a 30 feet by 40 feet rectangular plan and two doors is assumed for Table 2. If exposed walls are 8 feet high, the gross wall area is 1120 square feet. The doors make up 39 ft^2, or 3.5 percent of the gross wall area and are assumed to have U = .10. For standard windows with storm (U=.56), Table 2 gives allowable window area as a percentage of gross wall area for various U-Values of the insulated wall portion. Note that larger amount of window area requires lower U-Value in the insulated wall. The chart also gives corresponding R-Values since this rating is commonly used in the construction business (any insulated wall with an R-Value equal to or greater than the chart would be acceptable.) R-Value is the reciprocal of U-Value (that is R=1/U).

TABLE 2. MAXIMUM WINDOW AREA ALLOWABLE FOR VARIOUS U-VALUE IN INSULATED FRAMED WALL
(assuming U_{avg} = .17 for wall group)

Maximum allowable window area (percent of gross wall area)[4]	U-Value of insulated wall	Minimum R-Value in insulated walls[5]
10	.128	8
15	.101	10
20	.071	14
25	.037	27
23	.014	70

Use the worksheet for determining if your plan meets the code requirements for wall-group U-Value if you wish to have large window areas. You may have to build with thicker walls. Thermal shutters[6] that are closed tightly on the insides of your windows every night or triple glass windows can also be used to improve your wall-group U-Value. You may want to build with a wall-group U-Value lower than code requires because of savings on future heating bills.

When planning window locations, remember that south windows can actually add heat from sunshine to your house (1) if your south wall is not shaded during the winter, and (2) if you cover the windows at night with shades, drapes, or shutters. If so, you may wish to locate over half your window area in the south wall and reduce the north wall windows to the minimum possible area.

[4] Equation 3 was used for calculating maximum window area.

[5] An R-Value of 70 would require a fully insulated wall approximately 2 feet thick, which would not be cost-effective in any design. A better approach would be to insulate windows at night or use triple glass windows. Large window areas designed for passive solar heating, for example, may require "moveable" insulation because R-Values above 30 are generally not practical for walls. Any design which meets the requirements for average U-Value is acceptable to meet the current Minnesota Energy Code.

[6] Thermal shutters could be made of 1" styrofoam sandwiched between ¼" plywood facing. Using the daytime U-Value of window plus storm (U=.560) averaged with a nighttime U-Value of shutter plus window plus storm (U=.107), the daily average U-Value is .333. Shutters should be closed every night during the winter if you claim the daily average U-Value in calculations to meet the energy code.

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Total Exposed Wall Area = ______________ (Total A)

Total U x A of Exposed Wall Parts = ______________ (Total B)

Average U (Exposed Wall) = ______________ (B divided by A)
(Does it meet code?)

Total Roof/Ceiling Area = ______________ (Total C)

Total U x A of Roof/Ceiling Parts = ______________ (Total D)

Average U (Roof/Ceiling) = ______________ (D divided by C)
(Does it meet code?)

HEAT LOSS PER YEAR — **COST PER YEAR**

-Value	U X A	U X A X 24 X Degree Days (per year) X Adjusted Heat Energy Price† ($ per million BTU) = Cost Per Year
	Total B	
	Total D	

Total of "Cost Per Year" Column	
Air Leakage Cost Per Year (Use Equation 1)	
Total Heating Cost Per Year	

How to Calculate Areas:

The backside of this worksheet will help you calculate the areas that you need to enter in the blanks on the front side. For the wall group, it is easiest to start with windows and doors first. Then "framed/insulated" wall area is the remainder of the wall *above* the rim joist. See figure 1 for location of the rim joist. The wall *below* the rim joist is foundation (usually made of concrete blocks). Once again, the easiest method is begin with measuring and counting the windows in the foundation wall. Then "foundation wall" is the remainder of the wall below the rim joist (but above ground level). Follow the steps outlined below for easy calculations.

Windows, Type 1 ____________________

Width X	Height X	Number =	Area
		SUBTOTAL SQ FT	

(enter in worksheet)

Windows, Type 2 ____________________

Width X	Height X	Number =	Area
		SUBTOTAL SQ FT	

(enter in worksheet)

Doors, Type ____________________

Width X	Height X	Number =	Area
		SUBTOTAL SQ FT	

(enter in worksheet)

Other Window or Door Type ____________________

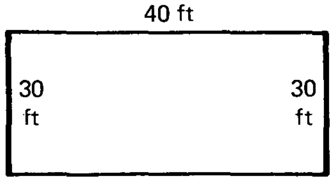
Width X	Height X	Number =	Area
		SUBTOTAL SQ FT	

(enter in worksheet)

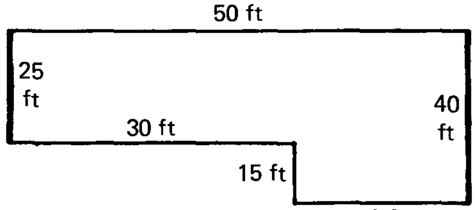
1. **Add together subtotals:**
   (Note: basement windows not included)
   WINDOW/DOOR AREA = ____________________ sq ft

2. **Next, determine the perimeter of your house (or house plan).**

   Samples:

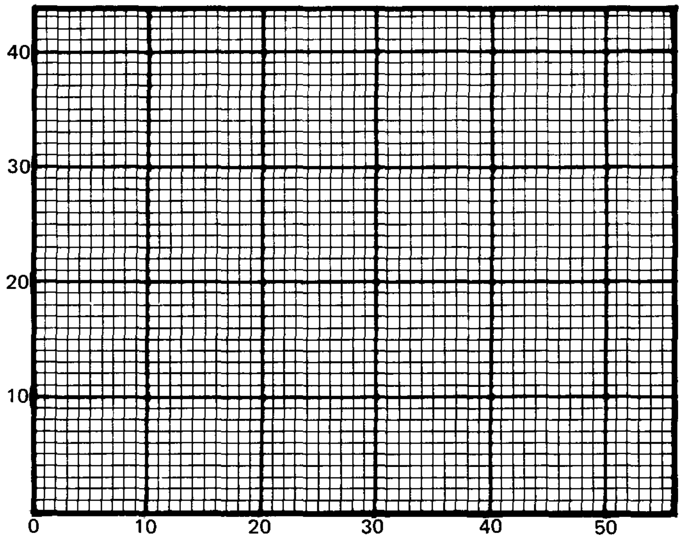


40
40
30
+30
140 ft = Perimeter



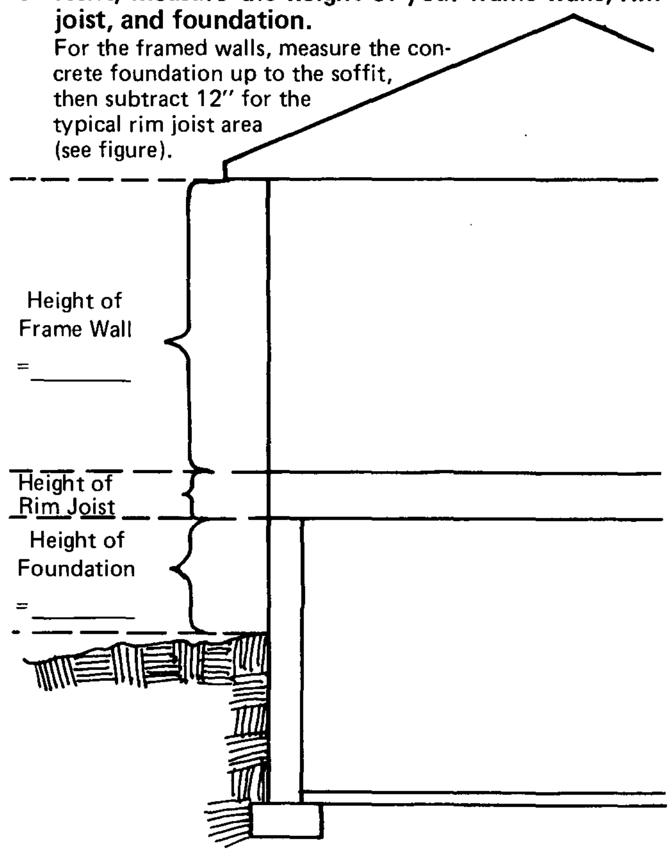
50
40
20
15
30
+25
180 ft
= Perimeter

Sketch you house plan here:



PERIMETER = ____________

3. **Next, measure the height of your frame walls, rim joist, and foundation.**
   For the framed walls, measure the concrete foundation up to the soffit, then subtract 12" for the typical rim joist area (see figure).



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Total Exposed Wall Area = ______________ (Total A)

Total U x A of Exposed Wall Parts = ______________ (Total B)

Average U (Exposed Wall) = ______________ (B divided by A)
(Does it meet code?)

Total Roof/Ceiling Area = ______________ (Total C)

Total U x A of Roof/Ceiling Parts = ______________ (Total D)

Average U (Roof/Ceiling) = ______________ (D divided by C)
(Does it meet code?)

Value	U X A	HEAT LOSS PER YEAR: U X A X 24 X Degree Days (per year) X Adjusted Heat Energy Price† ($ per million BTU) = COST PER YEAR: Cost Per Year
	Total B	
	Total D	

Total of "Cost Per Year" Column	
Air Leakage Cost Per Year (Use Equation 1)	
Total Heating Cost Per Year	

How to Calculate Areas:

The backside of this worksheet will help you calculate the areas that you need to enter in the blanks on the front side. For the wall group, it is easiest to start with windows and doors first. Then "framed/insulated" wall area is the remainder of the wall *above* the rim joist. See figure 1 for location of the rim joist. The wall *below* the rim joist is foundation (usually made of concrete blocks). Once again, the easiest method is begin with measuring and counting the windows in the foundation wall. Then "foundation wall" is the remainder of the wall below the rim joist (but above ground level). Follow the steps outlined below for easy calculations.

Windows, Type 1 ____________________

Width X	Height X	Number =	Area
		SUBTOTAL SQ FT	

(enter in worksheet)

Windows, Type 2 ____________________

Width X	Height X	Number =	Area
		SUBTOTAL SQ FT	

(enter in worksheet)

Doors, Type ____________________

Width X	Height X	Number =	Area
		SUBTOTAL SQ FT	

(enter in worksheet)

Other Window or Door Type ____________________

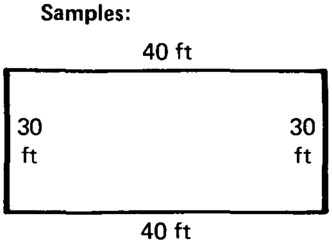
Width X	Height X	Number =	Area
		SUBTOTAL SQ FT	

(enter in worksheet)

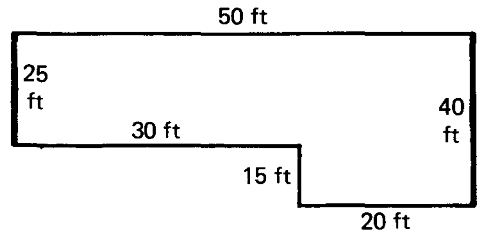
1. **Add together subtotals:**
   (Note: basement windows not included)
   WINDOW/DOOR AREA = ____________________ sq ft

2. **Next, determine the perimeter of your house (or house plan).**

Samples:

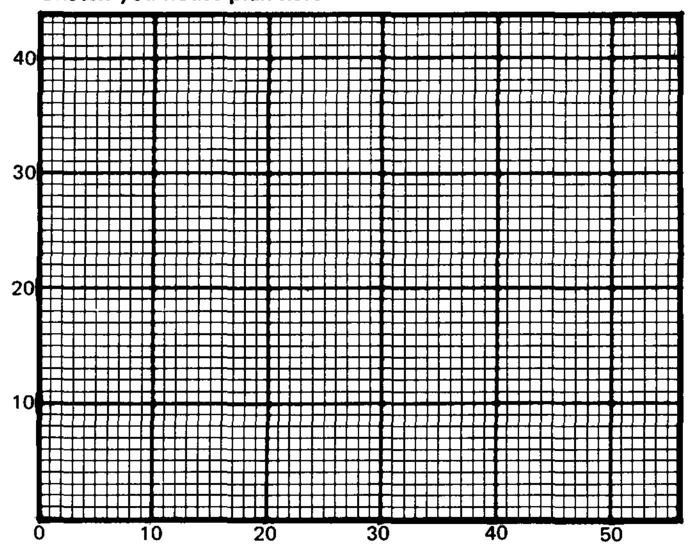


40
40
30
+30
140 ft = Perimeter



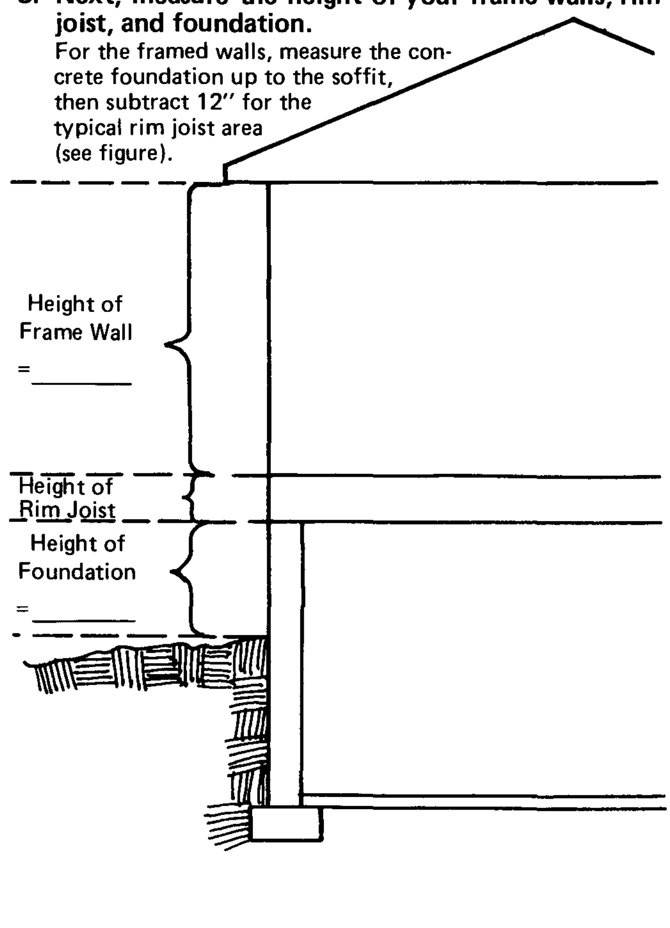
50
40
20
15
30
+25
180 ft
= Perimeter

Sketch you house plan here:



PERIMETER = ____________

3. **Next, measure the height of your frame walls, rim joist, and foundation.**
   For the framed walls, measure the concrete foundation up to the soffit, then subtract 12" for the typical rim joist area (see figure).



4. Multiply perimeter X height of frame wall =

GROSS FRAME WALL AREA = ____________

5. Subtract window/door total from gross frame wall area to find "framed/insulated" wall area

Gross Frame Wall Area ____________

Subtract Window/Door Total ____________

FRAMED/INSULATED WALL AREA [sq ft]

(enter in worksheet)

6. Multiply perimeter X height of rim joist (usually 1 ft) =

RIM JOIST AREA [sq ft]

(enter in worksheet)

7. Measure basement windows (and doors if you have walkout basement)

Basement Windows

Width X	Height X	Number =	Area
		SUBTOTAL SQ FT	

(enter in worksheet)

Other Type Basement Windows (or Doors)

Width X	Height X	Number =	Area
		SUBTOTAL SQ FT	

(enter in worksheet)

Add together subtotals:

BASEMENT WINDOW/DOOR AREA = ____________ sq ft

8. Multiply perimeter X height of foundation wall =

GROSS FOUNDATION WALL AREA ____________ sq ft

9. Subtract basement window/door area from gross foundation wall area to find "foundation" wall area:

Gross Foundation Wall Area ____________

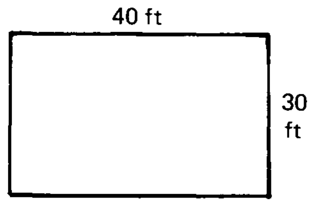
Subtract Basement Window/Door Area ____________

FOUNDATION WALL AREA 9 [sq ft]

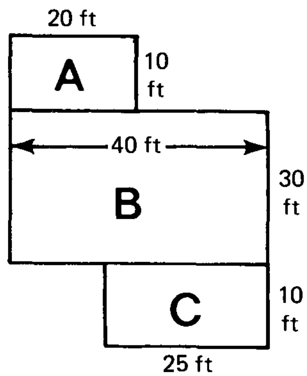
(enter in worksheet)

10. Next, calculate your ceiling area

Samples:



Ceiling Area = 40 X 30 = 1200 sq ft



A: 20 X 10 = 200
B: 30 X 40 = 1200
C: 10 X 25 = 250
Ceiling Area = A+B+C = 1650 sq ft

Your ceiling plan usually will be the same as the floor plan. If you have a finished attic, however, you must measure up the finished ceiling areas. Knee-walls and end-walls should be added to the "framed/insulated wall" area in the exposed wall group. Skylight areas (if you have skylights) should be subtracted from your gross ceiling area to get "framed/insulated" ceiling area.

Gross Ceiling Area ____________

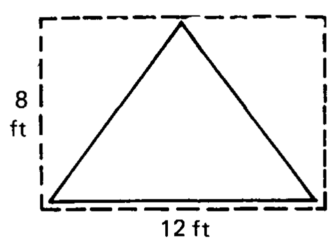
Subtract Skylights ____________

INSULATED CEILING AREA 10 [sq ft]

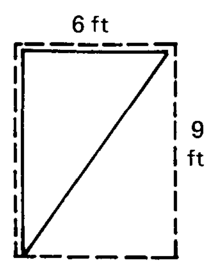
(enter in worksheet)

Hint: Triangular areas (such as in end-walls of finished attics) can be calculated by drawing a rectangle that "fits", then taking one half the area of the rectangle.

Examples:



$\frac{8 \times 12}{2}$ **= 48 sq ft**



$\frac{9 \times 6}{2}$ **= 27 sq ft**

Worksheet for Planning Ho

(One and two fa

Supplement to Extension Folde
and Energy Conservation Codes,
Extension Service, University of

Owner ______________________________

Site Address ______________________________

Contractor ______________________________

Degree-days ______________________________
(See Appendix 1)

Group	Part of Envelope	Specifications	Area (A)* (sq. ft.)	U-
Exposed Wall U-Value not more than ____ required by code (see Appendix 1)	Framed/insulated wall	Stud size Stud spacing Cavity insulation Sheathing		
	Windows, type 1			
	Windows, type 2			
	Doors			
	Rim joist area			
	Foundation wall (above ground)			
	Foundation windows			
	Other parts:			
			Total A	
Ceiling Roof U-Value not more than .04 required by code	Framed/insulated area			
	Skylight(s)			
	Other parts:			
			Total C	

*See the back side of this worksheet for hints on how to calculate areas.

†Adjusted **Heat** Energy Price = Local Energy Price X Inefficiency Factor. (See table 3 on page 10 of Extension Folder 389 for Inefficiency Factor, which accounts for the heating system inefficiency.)

4. Multiply perimeter X height of frame wall =

GROSS FRAME WALL AREA = ____________

5. Subtract window/door total from gross frame wall area to find "framed/insulated" wall area

Gross Frame Wall Area ____________

Subtract Window/Door Total ____________

FRAMED/INSULATED WALL AREA [sq ft]
(enter in worksheet)

6. Multiply perimeter X height of rim joist (usually 1 ft) =

RIM JOIST AREA [sq ft]
(enter in worksheet)

7. Measure basement windows (and doors if you have walkout basement)

Basement Windows

Width X	Height X	Number =	Area
		SUBTOTAL SQ FT	

(enter in worksheet)

Other Type Basement Windows (or Doors)

Width X	Height X	Number =	Area
		SUBTOTAL SQ FT	

(enter in worksheet)

Add together subtotals:

BASEMENT WINDOW/DOOR AREA = ____________ sq ft

8. Multiply perimeter X height of foundation wall =

GROSS FOUNDATION WALL AREA ____________ sq ft

9. Subtract basement window/door area from gross foundation wall area to find "foundation" wall area:

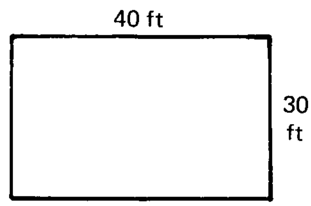
Gross Foundation Wall Area ____________

Subtract Basement Window/Door Area ____________

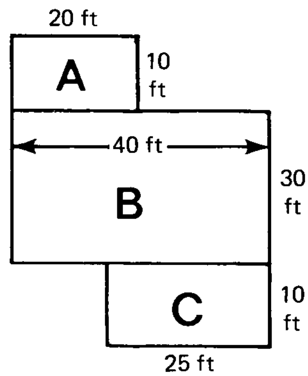
FOUNDATION WALL AREA 9 [sq ft]
(enter in worksheet)

10. Next, calculate your ceiling area

Samples:



Ceiling Area = 40 X 30 = 1200 sq ft



A: 20 X 10 = 200
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C: 10 X 25 = 250
Ceiling Area = A+B+C = 1650 sq ft

Your ceiling plan usually will be the same as the floor plan. If you have a finished attic, however, you must measure up the finished ceiling areas. Knee-walls and end-walls should be added to the "framed/insulated wall" area in the exposed wall group. Skylight areas (if you have skylights) should be subtracted from your gross ceiling area to get "framed/insulated" ceiling area.

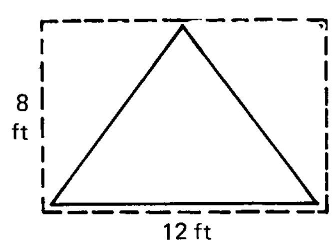
Gross Ceiling Area ____________

Subtract Skylights ____________

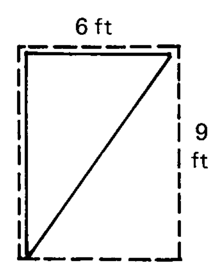
INSULATED CEILING AREA 10 [sq ft]
(enter in worksheet)

Hint: Triangular areas (such as in end-walls of finished attics) can be calculated by drawing a rectangle that "fits", then taking one half the area of the rectangle.

Examples:



$\frac{8 \times 12}{2}$ **= 48 sq ft**



$\frac{9 \times 6}{2}$ **= 27 sq ft**

Worksheet for Planning H(

(One and two fa

Supplement to Extension Folde
and Energy Conservation Codes,
Extension Service, University of

Owner ____________________

Site Address ____________________

Contractor ____________________

Degree-days ____________________
(See Appendix 1)

Group	Part of Envelope	Specifications	Area (A)* (sq. ft.)	U
Exposed Wall U-Value not more than ____ required by code (see Appendix 1)	Framed/insulated wall	Stud size Stud spacing Cavity insulation Sheathing		
	Windows, type 1			
	Windows, type 2			
	Doors			
	Rim joist area			
	Foundation wall (above ground)			
	Foundation windows			
	Other parts:			
			Total A	
Ceiling Roof U-Value not more than .04 required by code	Framed/insulated area			
	Skylight(s)			
	Other parts:			
			Total C	

*See the back side of this worksheet for hints on how to calculate areas.

†Adjusted **Heat** Energy Price = Local Energy Price × Inefficiency Factor.
(See table 3 on page 10 of Extension Folder 389 for Inefficiency Factor, which accounts for the heating system inefficiency.)

CEILING CONDUCTION AND ENERGY CODE REQUIREMENTS

The U-Value requirement for the roof-ceiling area of houses is more stringent than for the wall group, for two reasons: (1) warm air rises to ceilings and thus temperature difference would be somewhat greater than for walls, (2) added insulation in the attic generally does not cost as much as added insulation in walls (because cavity area in walls is limited). The Minnesota Energy Code requires that the average U-Value of the gross ceiling area be no greater than .04, which is the same as a minimum R-Value of 25.

If skylights penetrate a portion of the ceiling area, another balancing of U-Values and areas is needed to satisfy the energy code. Find the U-Value and area of the skylights, and then determine what U-Value you need in the insulated roof portion by using Equation 4.

EQUATION 4. AVERAGE U-VALUE IN CEILING

$$\frac{U_C A_C + U_S A_S}{A_{Total}} = .04 \text{ (or lower)}$$

U_c = U-Value insulated ceiling

A_c = Area of insulated ceiling

U_s = U-Value of skylight

A_s = Area of skylight(s)

A_{Total} = Total gross area of ceiling ($A_c + A_s$)

FLOOR CONDUCTION AND ENERGY CODE REQUIREMENTS

This section applies only to houses with added rooms over crawl space foundations or houses without basements. The energy code requires that any floor over an unheated crawl space must have a U-Value no higher than .08. This would require insulation of R-11 to be added under the wood subfloor.

USING WORKSHEET FOR PLANNING HOME ENERGY IMPROVEMENTS

The worksheet is arranged with the wall group of parts first (windows, rim joist, doors, foundation wall, and insulated wall). The ceiling group appears second. U-Values can be looked up from Table 1, unless a section is different than any shown in Table 1. In that case, use the R-Value method described in Appendix 2. Note that the worksheets can be removed from this folder by loosening the staples. The worksheet allows you to estimate the cost per year of the heat lost through any part of the house. An extra worksheet is provided because you may want to study the energy savings from better U-Values, smaller windows, less number of windows, or a smaller house. Try working through the first time to satisfy the Minnesota energy code requirements (see left side of worksheet). Start with the amount of window area you would like to have, and figure window area as a percent of gross wall area. Then refer to Table 2 to see approximately what type of insulated wall you will need to go along with your selected window area.

ENERGY PRICES AND HEATING COST

The column of the worksheet headed by "heat loss per year" gives the annual heat loss of each part of the house. The next column to the right, "adjusted heat energy price", is calculated just once using Equation 5 below. Call your local utility or fuel dealer to ask for the price of energy you use for heating (natural gas, oil, propane, or electric). Ask for the price per million BTU. If you cannot obtain this information, see Table 4 for approximate prices by region. If you know your price per gallon (oil or propane), thousand cubic feet (gas), or kilowatt-hour (electricity), use Table 5 to convert into price per million BTU ($ per MMBTU). Adjustment for heating inefficiency is then needed because some furnaces get less "mileage" from the fuel you purchase. See Table 6 for abbreviations.

EQUATION 5. ADJUSTED HEAT ENERGY PRICE

______	=	______	X	______
ADJUSTED HEAT ENERGY PRICE ($ per million BTU)		HEATING INEFFICIENCY FACTOR (from Table 3)		LOCAL ENERGY PRICE ($ per million BTU)

TABLE 3. HEATING INEFFICIENCY FACTOR

Heating System	Inefficiency Factor
Gas-fired furnace	1.43
Propane-fire furnace	1.43
Oil-fired furnace	1.54
Electric heating	1.00

TABLE 4. APPROXIMATE LOCAL ENERGY PRICES (1977)[7]

Region	Natural Gas		Electricity-Base Rate[8]		Fuel Oil		Propane	
See Map	$ per MMBTU	$ per mcf	$ per MMBTU	¢ per kwh	$ per MMBTU	¢ per gal	$ per MMBTU	¢ per gal
1	$2.84	$2.84	$10.40	3.55¢	$4.94	45¢	$4.40	40¢
2	$2.85	$2.85	$11.19	3.82¢	$4.94	45¢	$4.51	41¢
3	$2.51	$2.51	$13.36	4.56¢	$4.94	45¢	$4.62	42¢
4	$2.60	$2.60	$10.14	3.46¢	$4.94	45¢	$4.84	44¢
5	$2.20	$2.20	$10.14	3.46¢	$4.94	45¢	$5.06	46¢
6E	$2.05	$2.05	$11.34	3.87¢	$4.83	44¢	$4.51	41¢
6W	$2.06	$2.06	$12.39	4.23¢	$4.83	44¢	$4.40	40¢
7E	$2.14	$2.14	$ 8.76	2.99¢	$4.83	44¢	$4.73	43¢
7W	$2.10	$2.10	$12.54	4.28¢	$4.83	44¢	$4.40	40¢
8	$2.27	$2.27	$ 7.85	2.68¢	$4.83	44¢	$4.18	38¢
9	$1.87	$1.87	$12.80	4.37¢	$4.83	44¢	$4.73	43¢
10	$1.74	$1.74	$11.95	4.08¢	$4.83	44¢	$4.40	40¢
11	$1.94	$1.94	$12.74	4.35¢	$4.83	44¢	$4.73	43¢

[7] Data from "Residential Energy Prices in Minnesota", September, 1977 by Janet Peterson, Minnesota Energy Agency, 150 E. Kellogg Boulevard, St. Paul, MN 55101 (612) 296-5175.

[8] Electricity is sometimes priced with a quantity discount. If you are a large user of electricity, such as for farming or space heating purposes, your overall rate may be lower than listed in Table 4. Examine your electricity bill and divide the total monthly charge by the number of kilowatt-hours used in the month, to obtain the average price you pay per kwh.

TABLE 5. ENERGY PRICE CONVERSION FACTORS

Energy Type	Pricing Units Used By Your Local Utility	Multiplier Factor to Convert Local Price to $ per MMBTU:
electricity	cents per kWh (kilowatt-hour)	2.930
natural gas	dollars per 100 cu ft (therm)	10.00
	dollars per 1000 cu ft (mcf)	1.00
fuel oil	cents per gallon	0.0709
propane	cents per gallon	0.1098

EXAMPLES: Electricity (4.2¢/kWh) x (2.93) = $12.30 per MMBTU
Propane (45¢/gal) x (0.11) = $4.95 per MMBTU
Natural Gas ($2.90/thousand cubic feet) x (1.0) = $2.95 per MMBTU
(25¢/hundred cubic feet) x (10.0) = $2.50 per MMBTU

TABLE 6. ABBREVIATIONS AND DEFINITIONS

MMBTU = One million British Thermal Units (also written 10^6 BTU).

Therm = One hundred cubic feet of natural gas.

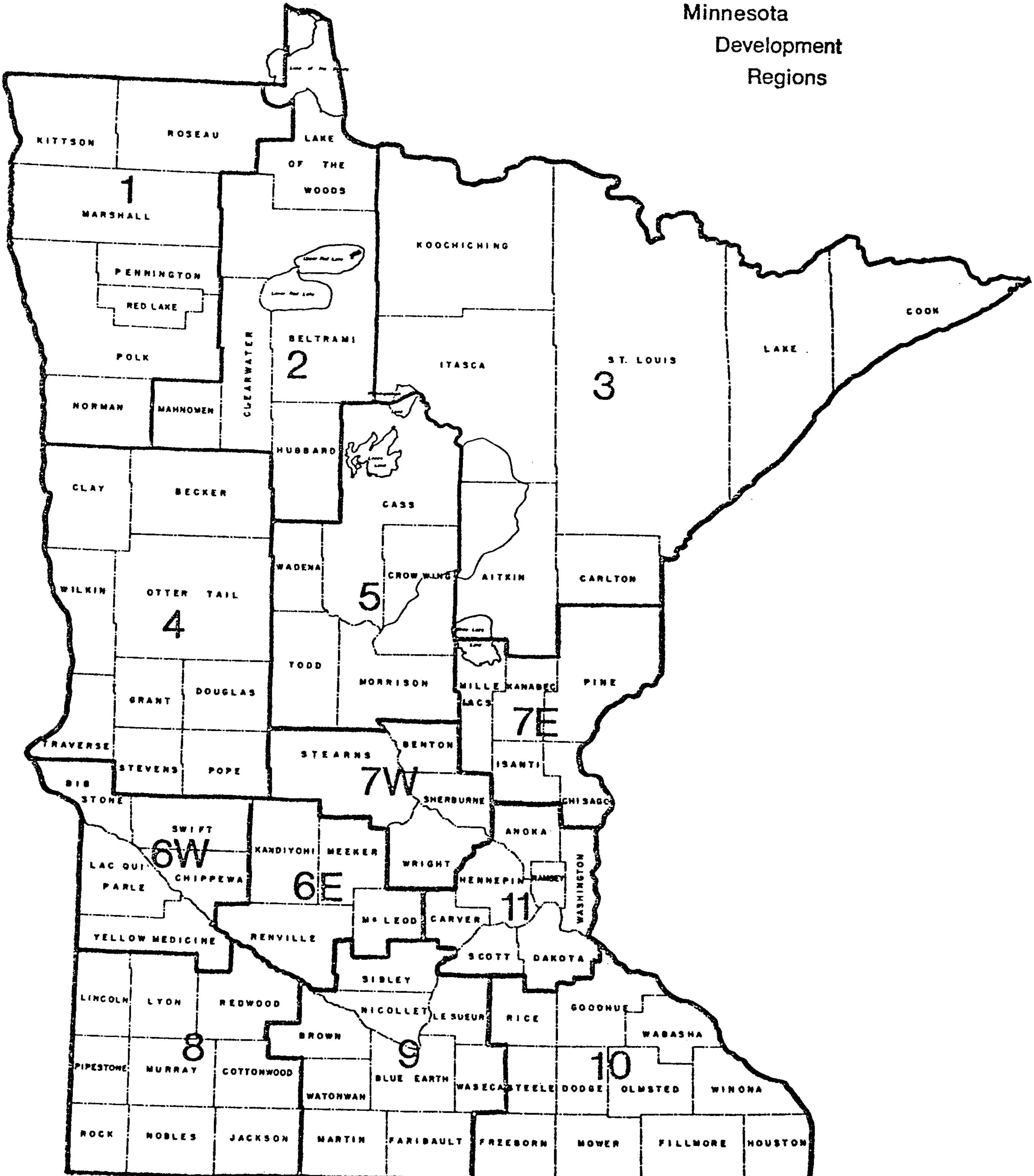
mcf = One thousand cubic feet of natural gas.

kWh = Kilowatt-hour (equal to one thousand watt-hours). A thousand watt load operated for one hour equals one kWh.

BTU = British Thermal Unit, defined as the energy needed to heat one pound of water by 1^oF. A BTU is about equal to the heat released from burning a wooden kitchen match.

After working through once, take a breather. Then take another worksheet and try it again to see what you can save by building better than code. For any part you improve (such as framed/insulated wall), compare the annual savings with extra "front-end" cost you have for better construction. For example, you may find that using higher R-Value sheathing will pay for itself in several years, but triple glass windows may require over ten years. Shop around to find the best improvements for your home-building dollars.

Minnesota Development Regions



APPENDIX 1. MINNESOTA ANNUAL HEATING DEGREE DAY NORMALS

ADA	9228	MADISON	8006
ALBERT LEA	7769	MAPLE PLAIN	8146
ALEXANDRIA	9235	MARSHALL	8032
ANGUS	9962	MEADOWLANDS	9745
ARGYLE	10206	MILACA	8704
ARTICHOKE LAKE	8402	MILAN	8429
AUSTIN	7907	MINN-ST. PAUL	8159
BABBITT	9846	MONTEVIDEO	8303
BAUDETTE	10098	MOOSE LAKE	9265
BEARDSLEY	8356	MORA	8684
BEMIDJI AIRPORT	10203	MORRIS	8815
BIG FALLS	9913	NEW LONDON	8360
BIRD ISLAND	8061	NEW ULM	7864
BRAINERD	9163	PARK RAPIDS	9707
CAMBRIDGE	8764	PINE RIVER DAM	9274
CAMPBELL	9253	PIPESTONE	8477
CANBY	7917	POKEGAMA DAM	9564
CHASKA	8039	RED LAKE FALLS	9694
CLOQUET	9567	RED LAKE INDIAN AGENCY	10112
CROOKSTON	9567	ROCHESTER	8227
DETROIT LAKES	9770	ROSEAU	10359
DULUTH	9757	ST. CLOUD	8868
FAIRMONT	7831	ST. PETER	7748
FAIRBAULT	7811	SANDY LAKE DAM LIBBY	9298
FARMINGTON	7937	SPRINGFIELD	7858
FERGUS FALLS	8790	TRACY	7900
FOSSTON	9439	TWO HARBORS	9130
GRAND MARAIS	9678	VIRGINIA	9694
GRAND MEADOW	8306	WADENA	9102
GRAND RAPIDS	9586	WALKER	9065
GULL LAKE DAM	8926	HARRBAD	10264
HALLOCK	10287	WASECA	8053
HINCKLEY	8976	WHEATON	8197
INTNL FALLS	10547	WILLMAR	8332
ITASCA STATE PARK	9799	WINDOM	7755
LEECH LAKE	9368	WINNEBAGO	8208
LITCHFIELD	8237	WINNIBIGBSHISH	9551
LITTLE FALLS	8730	WINONA	7511
LONG PRAIRIE	8997	WORTHINGTON	8276
		ZUMBROTA	7924

MAXIMUM AVERAGE U-VALUE IN EXPOSED WALL GROUP

Annual Degree-Days	Maximum U_{avg} (see Equation 3)
7000 - 8000	.19
8000 - 9000	.17
9000 - or above	.16

NOTE: Information for Appendix 1 has been taken from National Climatic Center, 1973 publication "Monthly Normals of Temperature, Precipitation & Heating and Cooling Degree Days, 1941-70, Minnesota".

APPENDIX 2. THE R-VALUE METHOD

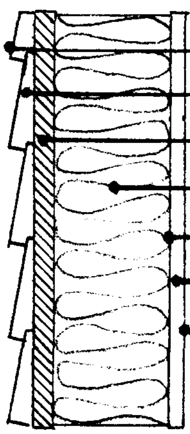
Each exterior section of a house is made of several layers. A wall, for example, is made of siding, sheathing, insulation, vapor barrier, and gypsum board. For thermal calculations, the air layer on each side of the wall is also included.

The "R-value method" is used one section at a time. The method is simply to add up the R-value of the layers in the section. The sum is the R-value of that section. R-value of insulating products is usually found on the package containing the material or on the material itself. For example, a 3½ inch fiberglass batt is typically R-11, and a 5½ inch batt is typically R-19. Be sure to check the actual rating of the material you plan to use. For approximate R-values of common building materials, see Table 3. The term "insulation" refers to products designed mainly to reduce the rate of heat transfer, but all building materials have some insulation value. R-value of a section should therefore include all materials and air layers.

An insulated framed wall is not a uniform section, because heat loss occurs through the studs at a higher rate than through the cavity between studs. The effect of "stud transmission" can be calculated by taking an average, with appropriate surface areas, of stud and cavity U-values. The extra calculations are probably not needed unless great accuracy is needed. A simple shortcut is to subtract 1 from the R-value for the cavity section. The same "rule-of-thumb" can be used for rafter transmission in ceilings with reasonable accuracy.

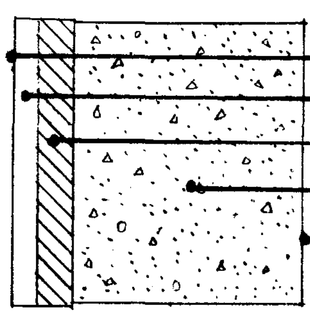
The following examples illustrate use of the R-Value method and Table 3.

EXAMPLE 1. FULLY INSULATED 2X4 WALL



	R-Value
outside air layer	.17
3/4" wood siding (3/4 x 1.25)	.94
25/32" insulating sheathing	2.06
3½" fiberglass batt	11.00
4 or 6 mil. polyethelene	- (negligible)
½" gypsum board	.45
inside air layer	.68
TOTAL =	15.30
R-Value =	15.30 - 1 = 14.30
U-Value =	1/14.30 - .070

EXAMPLE 2. INSULATED CONCRETE BLOCK WALL



	R-Value
outside air layer	.17
3/4" wood siding	.94
1" styrofoam	5.41
8" lightweight block	1.93
inside air layer	.68
Total R-Value =	9.13
U-Value =	1/9.13 = .109

TABLE 4. THERMAL RESISTANCE VALUES OF COMMONLY USED MATERIALS.[7]

Values do not include surface resistances

Material	Thermal resistance (R) per inch thickness	for thickness as manufactured
Batt or blanket insulation		
Glass wool, mineral wool, or fiberglass	3.0-3.7[8]	
3-3½ in. batt		11
5¼-6½ in. batt		19
Fill-type insulation		
Glass or mineral wool	2.2-3.6[8]	
Verminculite (expanded)	2.20	
Shavings or sawdust	2.20	
Cellulose products (milled pulverized paper or wood pulp)	3.70	
Rigid insulation		
Insulating board		
Sheathing, regular density ½ in.		1.25
Sheathing, regular density 25/32 in.		2.06
Expanded polystyrene, extruded, plain	4.00	
Expanded polystyrene, moulded beads	3.57	
Expanded polystyrene (aged)	6.25	
Glass fiber	4.00	
Ordinary building materials		
Face brick	.11	
Concrete, poured	.08	
Concrete block, 8 in.		1.04
Concrete block, 8 in. with cores filled		1.93
Light weight concrete blocks, 8 in.		2.18
light weight concrete blocks, 8 in. with cores filled		5.03
Plywood	1.25	
Plywood, 3/8 in.		.47
Plywood, ½ in.		.63
Hardboard, medium density	1.37	
Plasterboard 3/8 in.		.32
Plasterboard ½ in.		.45
Cement asbestos board	.25	
Lumber (fir, pine, and similar soft woods)	1.25	
Asphalt shingles		.44
Wood shingles		.94
Windows (includes surface resistances)		
Single glass		.89
Single glass with storm windows		1.79
Double-pane insulating glass 3/16 in. air space		1.45
Double-pane insulating glass ½ in. air space		1.73
Triple-pane insulating glass ¼ in. air space		2.12
Air spaces		
3/4 in. to 4 in.		.90
Surface resistances		
Inside surface (still air)		.68
Outside (15 mph wind)		.17

[7]From American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)Handbook of Fundamentals, 1972.

[8]Actual value depends on density and fiber diameter. Smaller fiber diameters and greater densities produce higher thermal resistances. Use R-Values (thermal resistance) as labeled by the manufacturer.

REFERENCES:

1. First Things First, What to Do Before Investing in Home Insulation, Extension Folder 386, written by the University of Wisconsin-Extension, available from your County Agricultural Extension Office. (Useful consumer tips on home energy improvements.)

2. In the Bank... or Up the Chimney, by the U.S. Department of Housing and Urban Development. Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, GPO Stock No. 023-000-00411-9, $1.70 (Gives illustrated instructions for installing caulk, weatherstripping, and insulation. Covers most situations in existing homes. Also has tips on getting estimates from contractors).

3. Conservation Guides 1-6, available from the Minnesota Energy Agency, 980 American Center Building, 150 East Kellog Boulevard, St. Paul, MN 55101, 296-5175, or toll-free call (800) 652-9028 from outstate.
    1. Home Energy Audit
    2. Ceiling Reinsulation
    3. Cooling Your Home
    4. Windows and Doors
    5. Weatherstripping and Caulking
    6. Domestic Water Heating

4. Home Energy How-To, by A.J. Hand, 1977, a Popular Science book, Harper and Row Publishers, $9.95. (Excellent illustrations and practical tips on weatherstrip, caulk, insulation, furnace maintenance, and solar heating).

5. The Solar Home Book, by Bruce Anderson, 1976, available from Chesire Books, Church Hill, Harrisville, NH 03950, $7.50. (Has good explanations of heat loss, air leakage estimates, and types of insulation. Also discusses moveable window insulation).

6. ASHRAE Standard 90-75, Energy Conservation in New Building Design, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, 1975, available from ASHRAE Circulation Sales Department, 345 E. 47th Street, New York, NY 10017, $10.35. (Minnesota State Building Code Energy Standards are based upon ASHRAE 90-75. Designers should realize that codes require minimum standards, and better thermal design is a good practice).

Single copies of Extension Folders are available free to Minnesota residents from your County Extension Office.

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